Densification of ICRS in the Optical by use of Old Pulkovo Observation Sets

Irina I. Kumkova

Institute of Applied Astronomy RAS, 10, Kutuzov emb, St. Petersburg 191187 Russia

Vadim V. Bobylev, Nina M. Bronnikova

Main Astronomical Observatory, Pulkovo, St.Petersburg, 196240, Russia

Abstract. Modern tasks of high precision astrometry demand optical coordinate systems including more faint stars than are available now in current conventional systems (Hipparcos). For this purpose it is suggested to use old photographic observations accumulated in the Pulkovo Observatory. Extensive observational data have been obtained at Pulkovo Observatory during the last century in the framework of several programs, *e.g.* Pulkovo Galaxy plan, *etc.* Observations have been made with the Normal Astrograph from 1894 to the present. The data are investigated with the aim of extending the Hipparcos catalog to stars fainter than 11th magnitude. All available observations are taken into account. A description of the material considered is given. The distribution of the selected plates over the celestial sphere is shown as well. Coordinates of faint stars in the Hipparcos system are calculated for selected areas. The accuracy of computed star coordinates is analyzed. Results of the investigation are presented.

1. Introduction

At the first astrometric conference (Pulkovo, 1932) an idea was proposed to compile the Fundamental Catalog of Faint Stars, and to use galaxies to determine absolute star proper motions. Later (in 1937) Prof. A.N. Deutsch demonstrated the possibility of connecting stars to galaxy NGC 4262 to determine absolute star proper motions. A list of areas with galaxies was compiled for such a goal by P. G. Kulikovsky and G. N. Neuimin in 1940. It consisted of 143 areas with 271 galaxies. The list was checked in Pulkovo, Moscow and Tashkent observatories. Regular observations of areas with galaxies started in Pulkovo observatory in 1939. The observations stopped during the Second World War and the following period of restoration from 1941 to 1949. Before the war, 123 plates with galaxies were obtained in Pulkovo and 94 plates in Tashkent from 1941 to 1949. In 1950 the observational list was re-checked. Some areas were excluded and several were added. In Pulkovo the observations were carried out using the Pulkovo Normal Astrograph (F=3.5 m, D=33 cm, plate $2^\circ \times 2^\circ$). As a result of all long-term work the catalog — PUL2 of 59646 star proper motions

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
MAR 2000	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Densification of ICRS in the Optical by Use of Old Pulkovo Observation Sets	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Naval Observatory 3450 Massachsuetts Avenue, N.W. Washington, DC 20392-5420**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
Towards models and constants for sub-microarcsecond astrometry, Proceedings of IAU Colloquium 180 held at the U.S. Naval Observatory, Washington, DC, USA, 27-30 March 2000

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**7**	

with respect to galaxies was completed for 149 areas of the northern hemisphere in 1999. The areas are distributed uniformly over declinations from $-5°$ to $+85°$. The first epoch of the photographic plates was obtained from 1937 to 1965, and the period of the second one is from 1969 to 1986. The mean difference of epochs is equal to 24 years. Three pairs of photographic plates were obtained for every area. All plates were taken with 1-hour and 5-minutes exposures. Bright stars were measured only on plates taken with a diffraction grating. Relative star proper motions were calculated using faint (mag 15) reference stars. A six-constant model has been used in the reduction of plates. 700 galaxies were used. Random errors of relative star proper motions were estimated for 18250 stars and are 5.5 mas/yr (milliarcsecond per year) for $\mu_\alpha \cos\delta$ and 5.9 mas/yr for μ_δ. Errors of fictitious proper motions of galaxies are 7.9 mas/yr (mean calibration error) for both coordinates. The mean random error of absolute bright star proper motions are equal to 9.3 mas/yr for $\mu_\alpha \cos\delta$ and 9.4 mas/yr for mu_δ derived from comparison of PUL2 and Hipparcos catalogs. Mean random errors of absolute faint star (41000 stars) proper motions in PUL2 are 7.9 mas/yr for both coordinates.

2. Calculations

The calculations were carried out for 5 areas selected from PUL2 for pilot work. Two areas are presented at Figs. 1–2. After reduction of star coordinates to the same epoch for both catalogs PUL2 and Hipparcos, an identification of common stars has been done. A six-constant model has been applied to the reduction of the plates. Hipparcos stars were used as references. The calculations were performed for 30 PUL2 stars. The resulting equatorial coordinates of PUL2 stars in different areas are presented in Tables 1–3 .

3. Conclusions

It is possible to use PUL2 — the catalog of 59646 stars proper motions with respect to galaxies — to extend the Hipparcos catalog to faint stars in the selected areas without significant loss of accuracy. Moreover the results of such an extension will give more material for the analysis of Galaxy kinematics.

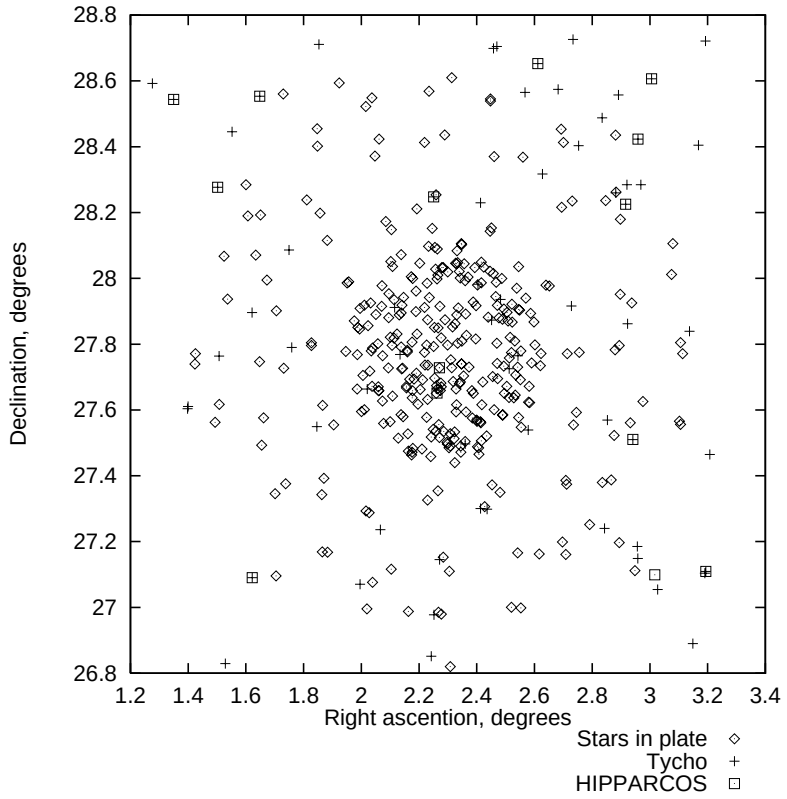
Declination, degrees
Right ascention, degrees
28.8
28.6
28.4
28.2
28
27.8
27.6
27.4
27.2
27
26.8
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4
Stars in plate
Tycho
HIPPARCOS

Figure 1.

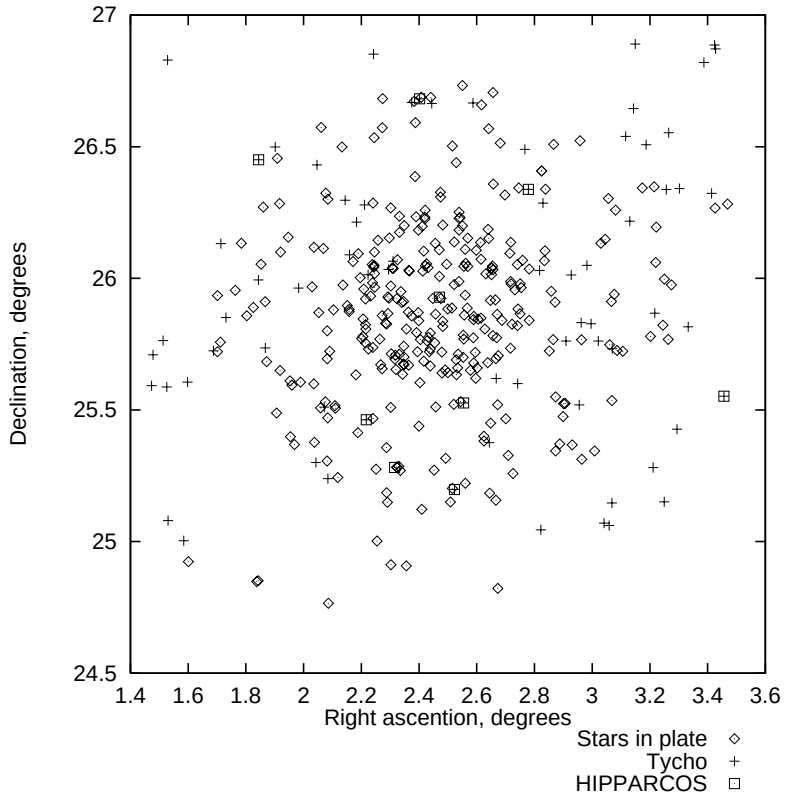
27
26.5
26
25.5
25
24.5
Declination, degrees
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
Right ascention, degrees
Stars in plate
Tycho
HIPPARCOS

Figure 2.

Table 1. $\alpha = 00^h\,09^m\,04\overset{s}{.}920$, $\delta = 27^\circ\,43'\,41\overset{''}{.}52$

	α				δ			
PUL2 Number	hh	mm	ss	σ_α, ss	δ, deg	δ, mm	δ, ss	σ_δ, ss
432	00	06	24.184	0.0009	27	58	16.41	0.002
10	00	06	53.303	0.0007	28	10	3.60	0.003
324	00	07	26.962	0.0005	27	26	6.79	0.002
206	00	07	53.121	0.0004	27	48	5.87	0.001
351	00	08	02.829	0.0003	27	29	57.48	0.001
201	00	08	08.232	0.0003	27	45	28.62	0.002
284	00	08	16.132	0.0003	27	51	28.75	0.001
285	00	08	23.278	0.0002	27	53	46.68	0.001
218	00	08	30.447	0.0002	27	48	38.69	0.001
124	00	08	36.404	0.0001	27	41	48.56	0.001
52	00	08	41.152	0.0001	27	35	31.22	0.001
190	00	08	45.137	0.0001	27	46	48.37	0.004
150	00	08	51.872	0.0001	27	43	49.72	0.001
276	00	08	55.477	0.0001	27	50	17.93	0.001
464	00	09	00.583	0.0001	27	41	47.48	0.001
318	00	09	02.795	0.0004	27	20	19.68	0.002
272	00	09	07.026	0.0002	27	53	10.15	0.001
332	00	09	11.894	0.0005	27	24	10.80	0.002
40	00	09	16.353	0.0004	27	34	30.56	0.001
184	00	09	18.866	0.0003	27	45	53.64	0.001
158	00	09	22.015	0.0001	27	43	54.63	0.001
182	00	09	26.418	0.0001	27	46	40.26	0.001
80	00	09	34.616	0.0002	27	38	32.55	0.001
307	00	09	38.850	0.0002	27	53	40.16	0.001
452	00	09	46.723	0.0002	28	9	14.62	0.003
162	00	09	51.762	0.0003	27	43	56.43	0.001
242	00	09	57.437	0.0003	27	49	9.29	0.006
245	00	10	4.202	0.0003	27	49	37.21	0.007
247	00	10	9.749	0.0004	27	49	5.60	0.006
96	00	10	18.269	0.0004	27	41	44.02	0.002

Table 2. $\alpha = 00^h\,09^m\,52\overset{s}{.}944$, $\delta = 25^\circ\,55'\,41\overset{''}{.}52$

	α				δ			
PUL2 Number	hh	mm	ss	σ_α, ss	δ, deg	δ, mm	δ, ss	σ_δ, ss
357	00	08	29.212	0.0005	25	53	06.20	0.002
326	00	08	38.591	0.0004	25	56	17.49	0.001
369	00	09	00.556	0.0003	25	49	59.13	0.006
330	00	09	01.315	0.0003	25	55	38.60	0.001
172	00	09	12.315	0.0002	25	51	52.85	0.004
111	00	09	19.178	0.0002	25	54	28.49	0.001
10	00	09	19.611	0.0002	25	58	39.68	0.004
257	00	09	18.696	0.0002	26	01	14.31	0.006
104	00	09	30.728	0.0001	25	53	49.79	0.002
393	00	09	38.410	0.0001	25	47	55.01	0.008
161	00	09	36.899	0.0001	25	52	30.69	0.003
68	00	09	36.841	0.0001	25	55	49.83	0.001
196	00	09	43.863	0.0001	25	51	03.60	0.005
230	00	09	50.275	0.0001	25	49	00.91	0.007
215	00	09	51.716	0.0001	25	50	04.27	0.006
46	00	09	49.259	0.0001	25	55	54.82	0.001
190	00	09	57.861	0.0003	25	51	20.30	0.004
40	00	09	56.002	0.0002	25	56	05.89	0.001
156	00	10	04.384	0.0002	25	51	44.62	0.004
234	00	10	10.108	0.0001	25	48	04.04	0.008
152	00	10	09.017	0.0001	25	52	15.83	0.003
123	00	10	12.009	0.0001	25	53	20.43	0.002
419	00	10	25.756	0.0002	25	42	35.76	0.003
120	00	10	20.606	0.0002	25	52	30.20	0.003
52	00	10	20.255	0.0002	25	55	28.12	0.001
289	00	10	22.058	0.0002	25	58	31.39	0.003
80	00	10	31.907	0.0002	25	53	45.66	0.001
385	00	10	50.679	0.0003	25	45	53.08	0.005
288	00	10	46.375	0.0003	25	57	21.63	0.002
277	00	11	02.152	0.0004	26	00	04.59	0.005

Table 3. $\alpha = 00^h\,42^m\,13\overset{s}{.}872$, $\delta = 40^\circ\,41'\,26\overset{''}{.}52$

	α				δ			
PUL2 Number	hh	mm	ss	σ_α, ss	δ, deg	δ, mm	δ, ss	σ_δ, ss
569	00	39	44.410	0.0008	40	37	54.77	0.003
642	00	40	24.188	0.0006	41	09	54.77	0.003
610	00	41	05.703	0.0004	40	59	49.02	0.002
198	00	41	21.630	0.0003	40	46	31.35	0.001
174	00	41	29.870	0.0002	40	44	06.81	0.001
404	00	41	35.899	0.0002	40	59	06.55	0.002
277	00	41	37.961	0.0002	40	51	40.72	0.001
142	00	41	41.996	0.0002	40	41	52.64	0.001
172	00	41	46.260	0.0001	40	44	06.31	0.003
353	00	41	50.814	0.0001	40	56	56.32	0.002
386	00	41	54.721	0.0001	40	58	08.85	0.002
441	00	41	57.823	0.0001	41	02	07.84	0.002
387	00	42	01.378	0.0001	40	58	45.00	0.002
402	00	42	03.335	0.0001	40	59	05.72	0.002
313	00	42	06.497	0.0001	40	54	15.14	0.001
254	00	42	09.259	0.0001	40	49	35.72	0.001
329	00	42	11.973	0.0001	40	55	06.79	0.001
125	00	42	15.150	0.0001	40	40	19.10	0.001
255	00	42	19.030	0.0001	40	50	11.59	0.001
111	00	42	21.778	0.0001	40	39	12.13	0.001
100	00	42	24.896	0.0001	40	38	36.09	0.002
217	00	42	27.628	0.0001	40	47	00.29	0.001
410	00	42	30.773	0.0001	41	00	12.43	0.002
444	00	42	33.520	0.0001	41	01	35.54	0.002
23	00	42	35.576	0.0001	41	34	29.62	0.001
232	00	42	39.349	0.0002	40	47	51.53	0.001
412	00	42	41.750	0.0002	41	00	01.70	0.002
433	00	42	45.282	0.0002	41	00	43.17	0.002
129	00	42	49.071	0.0002	40	41	19.75	0.002
287	00	42	50.318	0.0002	40	52	09.56	0.001

References

Deutsch, A.N., Lavdovsky, V.V., Fatchikhin, N.V., Gamalei, N.V., 1953, Izvestiay GAO N150, (in Russian).

Deutsch, A.N., Yakhontov, K.N., 1950, Working catalogue of 32 extragalactic nebulae, GAISH, M.